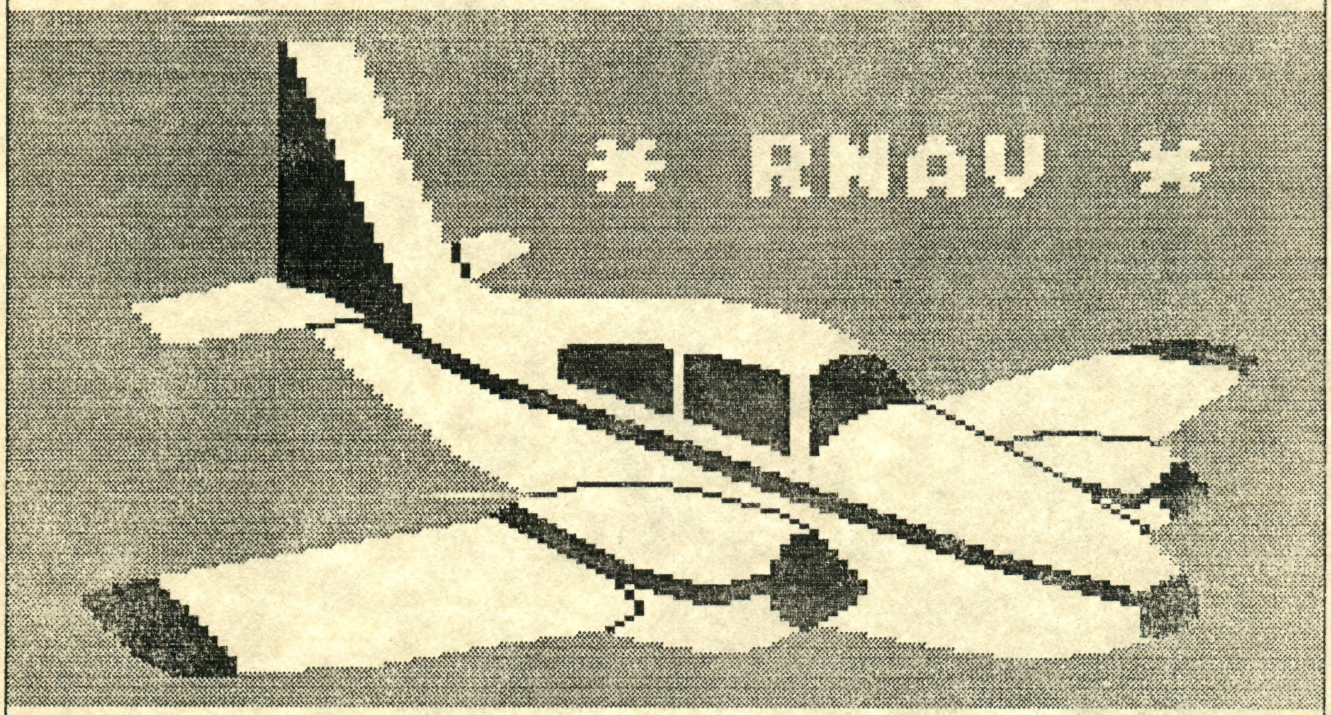
AIR NAVIGATION



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MANUAL

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AIR NAVIGATION/*RNAV*

by

Robert A. Tims

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AIR NAVIGATION/*RNAV*
INTRODUCTION

OVERVIEW: AIR NAVIGATION/*RNAV* will help you to easily plan your flight routes. It will figure your magnetic course and distance from and to airports, navaids, intersections, and waypoints. Your waypoints will be calculated along your route using the navaids you choose. You will know your total distance, leg and remaining distance.

The nav data file can remember up to 250 different airports and navaids and store them on the diskette. The nav data can be easily entered, edited, deleted, viewed, and printed. You can store up to 26 of your most frequently traveled routes on the diskette. The program will view the route on the screen or print it on paper for you (both forwards and backwards).

REQUIRED ACCESSORIES: ATARI BASIC or OSS Basic XL. 40K RAM. One disk drive.

OPTIONAL ACCESSORIES: Printer.

CONTACTING THE AUTHOR: Users wishing to contact the author about AIR NAVIGATION/*RNAV* may call (501) 935-7586 evenings and weekends.

PREREQUISITES: Since AIR NAVIGATION/*RNAV* is a flight route planning aid, a knowledge of aeronautical navigation is needed to use the program. Every student pilot is exposed to sufficient navigation principles to understand the terms and concepts used in AIR NAVIGATION/*RNAV*.

Some new pilots may not have been exposed to RNAV (Area Navigation). The examples in this manual will help explain what RNAV is. If there are questions about aeronautical navigation, including RNAV, consult a flight instructor.

AIR NAVIGATION/*RNAV*
GETTING STARTED

LOADING AIR NAVIGATION/*RNAV: Insert the BASIC Language Cartridge in the (left) cartridge slot of your computer. With your computer turned OFF, turn on the disk drive. When the BUSY light goes out, open the disk drive door and insert the AIR NAVIGATION/*RNAV* diskette with the label in the lower right-hand corner nearest you. (Use disk drive 1 if you have more than one drive.) Turn on your computer and your TV set. The program will load into computer memory and start automatically. The program diskette should be left in the disk drive so the program will be able to access the data files.

COMMANDS: All commands are one key stroke. The [RETURN] key need not be used after a command. The [0] key always returns you to the previous menu. Sometimes a "Y/N" response is asked for. Type [Y] for "Yes" and [N] for "No".

ENTERING DATA: Whenever data is prompted for, a data line the length of the spaces allowed will be displayed. Only the type of data requested will be accepted in order to help eliminate typo errors. You can use the [Delete/BACK S] to erase data you've entered. Data input is terminated with the [RETURN] key.

Data input may be declined by not entering any data and pressing the [RETURN] key. Declining input is an implied program command, and its effect on the program will be covered in each case.

DEGREE FORMAT: The first time you run the AIR NAVIGATION/*RNAV* program, and until nav data has been entered, the first screen you'll see after the title display will be the degree format options. This is the format used when entering the latitude and longitude coordinates. The degree, minute, and second format is used in the NOAA AIRPORT/FACILITY DIRECTORY. The degree, minute, and tenth of a minute format is used in the Jeppesen charts. The LAT/LNG FORMAT menu will display the two options, how they should be entered, and examples.

The top line of the LAT/LNG FORMAT menu displays the number of entries in the nav data file. The right side of the top line will show the current FORMAT option. It is possible to change your choice later, and reformat any data stored, by using one of the edit options.

Whenever you attempt to go to the Main Menu with an empty nav data file, you'll always be routed to the LAT/LNG FORMAT Menu first. Using the [0] RETURN TO MENU option will take you to the Main Menu without changing the

current Degree Format. If you have entered the LAT/LNG FORMAT Menu as an edit option, than the [0] option will take you back to the Edit Menu without changing the format.

When you start using this program it is setup for the [1] DEGREES, MINUTES, & SECONDS option. This format will be the default until you have chosen the [2] DEGREES, MINUTES, & TENTHS option and make entries into the nav data file. When the program stores the nav data it also stores the format choice you've made.

The program will display the coordinates using the format form. Please note that you'll be entering it in the entry form as shown in the display example. We are used to seeing angles displayed with their proper symbols. For example, 78 Degrees, 8 minutes, and 28 seconds is written as 78° 06' 28". However, for this program, you enter it as 78.0628.

MAIN MENU: [1] ROUTE ENTRY allows you to enter in the flight route you are planning. You enter your navigation fixes by their identifiers, starting with your departure point and sequencing to your destination. After your route is entered, the program displays it back so you can check it. If it is what you want then you'll move to the Navigation Menu.

[2] LOAD FLIGHT will list the flight routes you've stored along with the empty routes yet to be used. When you choose one of the routes it is displayed for you to confirm. If it is the one you wanted then you'll move to the Navigation Menu.

[3] AIRNAV DATA allows you to enter fix coordinates in the nav data file, edit, view, and print them.

[ESC] will allow you to exit the program. It will turn the control of the computer back to you and BASIC. The [ESC] option (here at the Main Menu and when printing the nav data) and the next one ([P]) are the only "hidden" commands in the program. All other options are displayed.

[P] allows you to enter printer codes. This option is discussed in detail in the section on printer codes.

[SYSTEM RESET] will reboot your system. If the program disk is in your disk drive the program will be reloaded.

AIR NAVIGATION/*RNAV*
AIRNAV DATA

INTRODUCTION: The program uses the latitude and longtitude coordinates to calculate the true course and distance between any two fixes. The magnetic course is obtained by adding the magnetic variation to the true course. The nav fixes should be identified by their National or ICAO location identifier.

The nav data file is used to store up to 250 fixes for your use. The identifier is all that is needed for the program to recall the coordinates once they are entered into the file.

Fixes are seperated into airports and navaids, because a navaid often has the same three letter identifier as the nearby airport. U.S. airports have four letter identifiers. The first letter (K - identifier for U.S.) is omitted most of the time, leaving the three letter identifier we commonly use. The Pilot/Controller Glossary defines navaids as any device "which provides point to point guidance information or position data to aircraft in flight." To most of us that means a VOR, VORTAC, TACAN, or NDB.

Location identifiers, coordinates, and magnetic variation can be obtained from the AIRPORT/FACILITY DIRECTORY, or similiar service. You can use the Directory at any FAA Flight Service Station if you don't have your own subscription. Your local airport would be another good source for the information.

AIRNAV DATA MENU: The top line of the Airnav Data Menu will display the number of entries and the degree format. The second line (in large letters) is the menu title. Then the five options, using keys [0] - [4], are:

[0] - Return to the Main Menu.
[1] - Enter data for navaids.
[2] - Enter data for airports.
[3] - Edit data that has been entered.
[4] - View entered data singly or scrolled on the screen; or printed on paper.

RETURNING TO THE MAIN MENU: The [0] key will return you to the Main Menu. If you have entered or edited any data the program processes it first. It sorts the nav data file by the identifiers, with navaids being listed before airports. The data, including the format option, will then be stored on the diskette.

DATA ENTRY: Press the [1] key to enter a navaid. Press the [2] key to enter data for an airport. The top of the screen will show the present entry number and the coordinate degree format. At the bottom of the screen, the prompt for the identifier will appear. The data input line for a navaid will be 3 spaces long. An airport identifier data input line is 4 spaces long. This lets you use the full ICAO location identifier of you you wish to retain the "K" for the international airports. If less than 4 characters is inputed the program will insert a blank space for the first character, allowing a four letter identifier to properly line up with the three letter identifers. If you decline entry the program will return you to the Airnav Data Menu.

Press the [RETURN] key after entering the identifier. The identifier will be moved up on the screen and the Latitude prompt will appear at the screen bottom. If the degree format is tenths of a minute instead of using seconds the data line will be 1 character shorter. The same will be true when the Longitude is prompted for. If entry is declined the program will move back to the identifier prompt.

The data input must be between 0 and 90.0000 or it will be rejected. This program will not accept negative latitude or longitude. An explaination is given in the section on program limitations. If the input for minutes or seconds is over 59 then it will be rejected. (i.e. An input of 89.3400 will be accepted while an input of 89.3360 would be rejected.)

After you have entered the latitude, press [RETURN] to continue. The latitude will be displayed on the screen with the identifier and the longitude prompt will appear at the bottom of the screen. If entry is declined the program will move back to the latitude prompt.

The data input must be between 0 and 180.0000 or it will be rejected. If the input for minutes or seconds is over 59 then it will be rejected. (i.e. An input of 179.0046 will be accepted while an input of 178.6046 would be rejected.)

After you have entered the longitude, press [RETURN] to continue. The longitude will be displayed under the identifier and latitude. The magnetic variation will be prompted for at the bottom of the screen. If entry is declined the program will move back to the longitude prompt.

The data line is 3 spaces long to allow to up to 2 numerical characters and one sign character. The sign character may be +, W, [SPACE], -, or E. The sign character may be entered before or after the numerical

portion of the variation. A variation of 4° East can be entered as "-4", "E4", "4-", or "4E". The program will display the entries such as "4-" and "4E" on the data line as "4 -" and "4 E". That is so a confusing entry such as "4-7" or "4E7" can not be accidently entered. The variation, 12° West, can be entered as "12", "+12", "W12", "12+", or "12W".

Press [RETURN] to continue. The data for the navaid or airport will be displayed on the screen. The prompt at the bottom of the screen will ask, 'IS THE DATA CORRECT [Y]/[N]?'

If you answer "No" by pressing [N] then the variation is prompted again. If you press [Y] for "Yes" the data will be stored in the nav data file and you will be prompted for the identifier of the next fix.

To return to the Airnav Data Menu it is necessary to be at the identifier prompt. Declining data entry at this point returns the program to the Airnav Data Menu. If you have entered data you do not want and are at the "data correct?" prompt you will have to press [N], decline variation entry, decline longitude entry, and decline latitude entry. You'll then be at the identifier prompt and by declining that entry you'll arrive at the Airnav Data Menu. You can abort data entry at any point by continually declining entries until you arrive back at the Airnav Data Menu.

If an entry of too many characters is attempted on a data line, the tone will sound and the data is reprompted.

DATA ENTRY ERROR MESSAGES: Whenever an error message is displayed the message, 'Push any key to continue-', will be displayed at the bottom of the screen.

If more than 250 entries are attempted the message, 'FULL MEMORY', will appear at the top of the screen.

The program will not allow an identifier to be duplicated. The same identifier may be used for an airport and a navaid, but two airports or navaids may not have the same identifier. If an attempt is made to enter an identifier already being used, the message, 'I ALREADY HAVE "ID" STORED IN WITH THE NAV DATA!', will be displayed. "ID" is the identifier that would have been duplicated.

AIR NAVIGATION/*RNAV*
AIRNAV DATA

SAMPLE FLIGHT: We will be using the following flight and its fixes as an example:

> We will depart from the McGhee Tyson airport at Knoxville, Tennessee. Using RNAV we will fly direct to Cowan Intersection, using a waypoint off of the Hinch Mountain Vortac. From Cowan we'll fly V-54N to the Rocket Vortac and V-54 to the Muscle Shoals Vortac. Then we will land at the Muscle Shoals airport in Alabama.

The coordinates for the airports are:

TYS	LAT 35° 48′ 45"	LNG 83° 59′ 34"	VAR 1° W
MSL	LAT 34° 44′ 43"	LNG 87° 36′ 37"	VAR 1° E

The coordinates for the navaids are:

TYS	LAT 35° 54′ 17"	LNG 83° 53′ 41"	VAR 1° W
HCH	LAT 35° 46′ 51"	LNG 84° 58′ 43"	VAR 1° E
CHA	LAT 34° 57′ 40"	LNG 85° 09′ 12"	VAR 1° E
RQZ	LAT 34° 47′ 49"	LNG 86° 38′ 02"	VAR 2° E
MSL	LAT 34° 42′ 24"	LNG 87° 29′ 29"	VAR 1° E

SAMPLE DATA ENTRY: We'll enter the data for the Knoxville Vortac, TYS. Starting from the Airnav Data Menu, press [1]. You will see the navaid data entry screen with the identifier prompt. Type in "TYS". Press [RETURN].

The data 'IDENTIFIER: TYS' will be displayed on the screen and you'll be prompted for the latitude. Type in "35.5417" and press [RETURN].

The data 'LATITUDE: 35° 54′ 17"' will be added to the display. You will now be prompted for the longitude.

To show how easy it is to correct a mistake lets enter incorrect data for the longitude. Enter "85.341" and press [RETURN]. The incorrect data 'LONGITUDE: 85° 34′ 10"' will be displayed along with the prompt for the variation.

To correct the entry return to the longitude prompt by declining entry. Press [RETURN] without any data entry and the previous screen will be displayed. This time input the correct data by typing "83.5341". Press [RETURN] and we are back at the variation prompt.

Type "1" and press [RETURN]. The screen will look like:

ENTRY: 1 FORMAT: DD° MM′ SS"

NAVAID DATA ENTRY

IDENTIFIER: TYS

LATITUDE: 35° 54′ 17"

LONGITUDE: 83° 53′ 41"

MAGNETIC VARIATION: 1° W

IS THE DATA CORRECT [Y]/[N]?

The data looks good, so press the [Y] key. The screen with the identifier prompt will appear. Enter the data for Hinch Mountain Vortac (HCH) and Muscle Shoals Vortac (MSL). Do not enter Rocket (RQZ) at this time. Enter the following for the Chattanooga Vortac so you can edit it later:

CAA LAT 35° 57′ 40" LNG 108° 09′ 12" VAR 1° E

After entering the navaid data, decline entry at the identifier prompt to return to the Airnav Data Menu. Press [2] and the identifier prompt for airport data entry will be displayed. Enter the data for the airports, TYS and MSL. When you type in the identifier, "TYS", you will see 'IDENTIFIER? TYS_' displayed. You could enter the identifier as " TYS", but the program will insert the blank space for you. The rest of the data entry is identical to entering data for the navaids.

NAV DATA EDITOR: Option '[3] EDIT' of the Airnav Data Menu will display the Edit Menu. The Edit Menu has four options displayed on the top line. [0] MENU will take you back to the Airnav Data Menu. [1] NAVAID & [2] AIRPORT will allow you to edit the data that has been entered into the nav data file. [3] FORMAT will take you to the Format Menu.

CHANGING THE DEGREE FORMAT: You may change the degree format you are using even if data has already been entered and stored. The [0] option will return the Edit Menu.

When you use the Format Menu [1] or [2] options the following prompt will appear at the bottom of the menu: 'YOUR CHOICE IS FORMAT OPTION #1(or 2) [Y]/[N]'. If the answer is [N] then the Format Menu is offered again. If the answer is [Y] and the format option is the same as the current format you will be returned to the Edit Menu (the same as the [0] option). If the format option is different than the current format the data will be reformatted and stored on the diskette before the Edit Menu is redisplayed. The more data you have stored, the longer it will take to reformat.

When you change the format from using seconds to using tenths of a minute, 90° 38' 47" will become 90° 38.8'. If you change it back, 90° 38.8' will then be 90° 38' 48" which is slightly different than what you started with. This difference can be as much as 3 seconds, which is insignificant as the most 3 seconds can be is about 300 ft.

EDITING THE NAV DATA: Editing the airports is the same procedure as editing the navaids. Although navaids are used in the explanation, the same rules apply to both.

Pushing the Edit Menu's [1] option will allow us to edit navaids. If this is not the option you wanted, you may return to the Edit Menu by declining entry.

If you try to call up a fix that is not in the file an error message will be displayed. For example, if we tried to edit data for the Memphis Vortac which is not in the file, the following message would be displayed in the center of the screen: 'MEM IS NOT IN THE NAV DATA!'

To call a fix for editing, type the identifier and press [RETURN]. It will be displayed with its associated data, the edit options, and the prompt: 'WHICH DO YOU WANT TO CHANGE?' The '[0] EXIT' option will give you the prior display prompting for a navaid identifier.

[1] ID will display the prompt for a new identifier at the bottom of the screen, while leaving the current data on the screen. The '[2] LAT' option will display the prompt for reentering the latitude, the '[3] LNG' option will prompt for reentering the longitude, and the '[4] VAR' option will prompt for a new magnetic variation. When the new data is prompted for, declining entry will leave the data unchanged. Inputing new data

and pressing [RETURN] will enter the change to the nav data file, change the data displayed, and prompt for another change.

The program will not accept an identifier that already has been used, including the current identifier that is being edited. As an example, if we tried to change TYS to HCH the message 'I ALREADY HAVE HCH STORED IN WITH THE NAV DATA!' would be displayed. When you continue, the program will return to the prompt for the navaid to be edited:

The '[5] DEL' is for delete. When you press the [5] key the following question will be asked at the bottom of the display (the TYS identifier is used for illustration): 'YOU WANT TO DELETE TYS [Y]/[N]?' If [N] is the answer, the prompt, 'WHICH DO YOU WANT TO CHANGE?' will be redisplayed. If the answer is [Y] that fix will be deleted and the program will return to the Edit Menu.

SAMPLE EDIT

For an example, we'll change the incorrect entry for the Chattanooga Vortac:

CAA LAT 35° 57' 40" LNG° 108 09' 12" VAR 1° E

to the correct entry:

CHA LAT 34° 57' 40" LNG 85° 09' 12" VAR 1° E

Starting from the Main Menu we need to call the Airnav Data Menu by pressing the [2] key. Then choose the Edit Menu with key [3]. The fix we'll be editing is a navaid so we need to use the '[1] NAVAID' option. After pressing the [1] key the word "NAVAIDS" will appear at the top line to let you know that the program does indeed expect to edit a navaid. At the bottom of the screen, you'll be asked: 'NAVAID IDENTIFIER? ___

If you pressed the [2] key by mistake, you would see a prompt for the airport identifier. To get back to the Edit Menu just decline entry. Press the [1] key and you'll see the prompt for the navaid identifier.

Type in "CAA" and press [RETURN] and you will see the data displayed with the edit options. You are now ready to edit the data for the Chattanooga navaid.

Press the [1] key and the display will prompt for a new identifier. Type in the correct identifer for Chattanooga, "CHA", and press [RETURN]. The

screen will display the change and ask for the next choice. To correct the latitude, press the [2] key. You will be prompted for the new latitude. Type in the correct latitude, "34.574" and press [RETURN]. The screen will display the correction and ask for the next change. Pressing the [3] key will display the longitude prompt. Type in the correct longitude, "85.0912" and press [RETURN]. If the magnetic variation needed correcting the procedure would be the same except for displaying the variation prompt by pressing the [4] key. After correcting the longitude the screen will show:

[1]ID [2]LAT [3]LNG [4]VAR [5]DEL [0]EXIT

EDIT NAV DATA

IDENTIFIER: CHA

LATITUDE: 34° 57′ 40"

LONGITUDE: 85° 09′ 12"

MAGNETIC VARIATION: 1° E

WHICH DO YOU WANT TO CHANGE?

It looks right and to exit we press the [0] key. The program will take us back to the Edit Menu.

VIEWING THE NAV DATA: After entering the data it is sometimes necessary check the contents of the nav data file. A list of the fixes entered can be very helpful. The program provides means for listing the fixes on the screen or printing them on paper. By choosing the '[4] VIEW' option in the Airnav Data Menu you will be able to look at or list the nav data.

After entering the nav data and before you return to the Main Menu, the data is stored in the file in the same order it was entered. The data will be scrolled or printed in the same unsorted order. When you return to the Main Menu, the data will be sorted and stored on the diskette. If you then scroll or print the data it will be in alphabetical order.

Pressing the [0] key will take you back to the Airnav Data Menu. The '[1] NAV' and '[2] ARP' options will allow you to look at the coordinates for a single navaid or airport. They both work identically, one for navaids and the other for airports. If you wanted to look at the coordinates for McGhee Tyson Airport press the [2] key. At the prompt 'AIRPORT IDENTIFIER? ____' type in "TYS" and press [RETURN]. The data will then be displayed. Pushing any key will take you back to the former display prompting for an airport identifier. To return to the View Nav Data Menu all you have to do is decline entry at this prompt.

SCROLLING THE NAV DATA: The '[3] SCROLL' option will scroll the nav data file on the screen. Hold down the [CTRL] key and press the [1] key at the same time to stop the screen. [CTRL][1] will also restart the scroll.

After all the entries have scrolled off the screen, the program returns to the View Nav Data Menu. To return to the View Nav Data Menu before the scroll is finished, press [0]. However, if the screen has been stopped with [CTRL][1] it will have to be restarted before you will be able to return to the menu.

PRINTING THE NAV DATA: The '[4] PRINT' option will print the nav data for you. It prints 50 nav fixes per page and numbers the page. If there is a problem with the printer (such as it being turned off, deselected, or nonexistent) the program displays the View Nav Data Menu.

To discontinue the printout before it is finished, press the [ESC] key.

If the printer codes have not been entered, the data will be printed in the default font and margin of your printer and the degree symbol will not be printed. See the section on printer codes for instructions and suggestions on entering printer code for the degree character and printer initialization.

If you are using a 40 column printer the data still prints out in a readable format. Each line of data becomes two lines.

AIR NAVIGATION/*RNAV*
ROUTE ENTRY

TYPES OF NAV FIXES: AIRPORTS may be used for the departure and destination points as well as enroute fixes. They will be identified by their 3 or 4 character identifier.

NAVAIDS can be used for departure and destination points, enroute fixes, and as a reference fix for waypoints and intersections. They will be identified by their 3 letter identifier.

INTERSECTIONS are enroute fixes, but may be used for departure and destination points. An intersection needs a reference navaid with an offsetting radial and distance. In our sample flight we will be navigating to the COWAN Intersection which is defined as being 38 NM from the Chattanooga Vortac on its 227° radial. It is printed:

COWAN INTERSECTION * CHA 277.0° 38.0 NM

If you want to enter a waypoint (previously computed) by its reference navaid, radial, and distance it will need to be entered as an intersection.

WAYPOINTS are enroute fixes and require a reference navaid. The program will compute the bearing and distance for the offset of the waypoint from the navaid. Waypoints will be identified by the identifier of the reference navaid followed by the radial and distance from the navaid to the waypoint. The waypoint off of the Hinch Mountain Vortac used in our sample flight is printed:

HCH WAYPOINT 153.1° 19.3 NM

If the departure or destination point is an airport, the program will allow the input of a terminal waypoint that is offset over the airport. In our sample flight we use the Knoxville Vortac as a terminal waypoint for the McGhee Tyson Airport. The airport and terminal waypoint are printed together for easy identification:

TYS AIRPORT * TYS 221.9° 7.3 NM

DEPARTURE POINT: The first route prompt will ask you what type of fix you want to use for a departure point. Aircraft always use an airport for the departure point, however for planning purposes the program will also let you use a navaid or an intersection. Pressing the [1] key will indicate a navaid. Pressing the [2] key will indicate an airport. And pressing the [3] key indicates an intersection. If entry is declined, the program will return to the Main Menu.

After entering the type of fix for the departure point, you will be prompted for its identifier. Declining entry will return you to the departure fix prompt.

TERMINAL WAYPOINT: If the departure point is an airport, the program will prompt for a reference navaid for a terminal waypoint. If the departure point is not an airport the next prompt will be for an enroute fix. If a terminal waypoint is not desired, decline entry and the program will go to the enroute fix prompt. The top line of the display will include the identifier of the airport.

ENROUTE FIX ENTRIES: The program will be prompting for the navigation fixes that will be used enroute. The fixes will need to be entered in the order that they will be flown. First, you're asked for the type of fix that will be used next. In the prompt displays the last fix and asks for the next. This makes it easy to remember where you are in the route.

If a navaid or airport is given for the next fix, then the program will ask for the identifier. Whenever the identifier is prompted for, the type of fix will be identified above it. If it is the wrong type of fix then decline entry. If input is declined the program will return to the previous prompt for the type of fix.

The program searches the nav data file for the identifier. If it isn't found, the program prompts for the coordinates and variation. The entry for them is the same format and procedure as found in the AIRNAV DATA portion of the program. After you enter the data and confirm that it is correct you have the option to store the fix and its coordinates in the nav data file. The following prompt appears at the bottom of the display: 'STORE WITH THE NAV DATA [Y]/[N]?' If the choice is [Y] the data will be stored in the nav data file. The [N] choice will store the coordinates in the Route file. The program then prompts for the next fix.

ENROUTE INTERSECTION: When the next fix is going to be an intersection the program prompts for the name of the intersection. Intersection identifers are given on the charts as a five-letter name. The program allows for an entry of up to 5 letters.

The program prompts for the reference fix next. If entry is declined, the program returns to the prompt asking for the next enroute fix. When the identifier for the reference fix is entered, the program will search

the nav data file for it. If the data isn't located, the program will prompt for the coordinates and give you a chance to store them in the nav data file.

Once the reference fix has been entered the program prompts for the radial from the reference fix to the intersection. Five spaces are allowed for the radial which may be between 0° and 360°.

The distance from the reference fix to the intersection is prompted for next. Four spaces are allowed for the distance and may be between 0 and 99.9 NM.

If input is declined for the radial or distance the program returns to the last prompt.

After the distance has been entered the program asks if the data is correct. If the answer is [N] the program prompts for the distance again. If the data is correct, press [Y], and the program will store the intersection data in the route file and prompt for the next fix.

ENROUTE WAYPOINT: If the next enroute navigation fix is going to be a waypoint the program prompts for the reference navaid. If the navaid can't be found in the nav data file, the program prompts for the coordinates and variation, and give you a chance to store it in the nav data file.

The program will store all the waypoints in the route file that have been inputed. However, the program will ignore impractical waypoints when calculating the route. The following two situations are considered impractical:

1. A waypoint that would be behind the last fix.
2. A waypoint that would be ahead of the next non-waypoint fix.

The program calculates the waypoint is by using the radial from the reference navaid that is perpendicular to the route. Because the intersecting radial will always be perpendicular it is easy to note the location of the waypoint on your navigation chart.

DESTINATION POINT: The destination point is entered in as an enroute fix. When the next enroute fix prompt is displayed, decline entry and the program will exit the route planning. If the destination fix was an airport the program prompts for a terminal waypoint. If a terminal

waypoint is not desired, decline the entry.

MAXIMUM ENTRIES: The number of fixes that can be entered will vary on the type of fixes entered. The route file has room for 249 characters. Each fix requires 6 characters. An intersection requires an additional 13 characters. Every time the coordinates for a navaid or airport are stored in the route file instead of the nav data file, another 14 characters will be needed. If the route consists of only airports, navaids, and waypoints in the nav data file then 41 fixes will be able to be entered. If none of those are terminal waypoints, that's 40 legs. If there isn't any room left in the route file for the impending entry the program will display the message: 'NO MORE ROOM!'

FLIGHT ROUTE PREVIEW: After the route has been entered the program displays it on the screen so you can check it. The route scrolls up the screen from the bottom. If the route is over 12 legs the first part of the route will be scrolled off the screen. If you want to stop the scroll press [CTRL][1]. [CTRL][1] will start the scroll again. After the route has been listed on the screen the question will be asked: 'IS THE DATA CORRECT [Y]/[N]?' If you answer [N] the program starts over with the route entries. If the answer is [Y] the program continues to the Navigation Menu. If data was stored in the nav data file during route entry, it is sorted and stored to the diskette before continuing.

SAMPLE FLIGHT: We will be using the following flight and its fixes as an example:

> We will depart from the McGhee Tyson airport at Knoxville, Tennessee. Using RNAV we will fly direct to Cowan Intersection, using a waypoint off of the Hinch Mountain Vortac. From Cowan we'll fly V-54N to the Rocket Vortac and V-54 to the Muscle Shoals Vortac. Then we will land at the Muscle Shoals airport in Alabama.

The coordinates for the airports and navaids were entered during the sample data entry in the Airnav Data section, except for the Rocket Vortac data:

RQZ LAT 34° 47' 49" LNG 86° 38' 02" VAR 2° E

SAMPLE FLIGHT ENTRY: Press the [1] key for Route Entry while at the Main

Menu to see the prompt for the departure fix. The departure point is McGhee Tyson airport at Knoxville and pressing the [2] key will tell the program to prompt for an airport.

Type in the identifier, "TYS", and press [RETURN]. The program will then prompt for a terminal waypoint. By using the Knoxville Vortac as a waypoint located at McGhee Tyson, distance and groundspeed readouts will be possible. Type in the identifier for the Knoxville Vortac, "TYS", and press [RETURN].

The program will prompt for the next enroute fix. The next fix will be a waypoint using the Hinch Mountain Vortac. Press the [4] key and the program will prompt for the waypoint navaid. Type in the Hinch Mountain identifier, "HCH" and press [RETURN].

The program will prompt for the next fix, which is the COWAN intersection. Press the [3] key and the program will prompt for the identifier. Type in "COWAN" and press [RETURN]. The program will prompt for the reference navaid for the intersection. Type in the Chatanooga Vortac identifier, "CHA", and press [RETURN]. The program will prompt for the radial from the navaid to the intersection. Type in the 277° radial, "277", and press [RETURN]. The next prompt will be for the distance between the navaid and the intersection. Type in 38 NM, "38", and press [RETURN]. The program will ask if you are sure of the data. If the data is correct press [Y].

The program will prompt for the next fix which is the Rocket Vortac. Press the [1] key and the next prompt will be for the navaid identifier. Enter the identifier for the Rocket Vortac, "RQZ", and press [RETURN]. This fix is not in the nav data file, so the program will prompt for its coordinates starting with the latitude. Type in "34.4749" and press [RETURN]. The program will prompt for the longitude. Type in "86.3802" and press [RETURN]. The program will prompt for the magnetic variation. Type "E2" and press [RETURN]. If the data looks correct, press the [Y] key. Store the RQZ data in the nav data file by pressing the [Y] key at the prompt, 'STORE WITH THE NAV DATA [Y]/[N]?'

The program will prompt for the next enroute fix, which is the Muscle Shoals Vortac. Press the [1] key and the program will prompt for the navaid identifer. Type in the Muscle Shoals Vortac identifier, "MSL", and press [RETURN].

The program will prompt for the next enroute fix. Press the [2] key because the next fix is the destination airport. Enter the identifer for the Muscle Shoals, Alabama airport, "MSL" and press [RETURN]. The

program will prompt for the next enroute fix. The last fix was the destination, so decline entry by pressing [RETURN] and the program will exit the enroute fix entry mode. Because the last fix is an airport, the program will give the opportunity to enter a terminal waypoint. The terminal waypoint isn't needed so decline entry by pressing [RETURN]. The route will then be displayed for correctness:

TYS TO MSL

FLIGHT ROUTE

TYS AIRPORT * WAYPOINT TYS
HCH WAYPOINT
COWAN INTERSECTION
RQZ NAVAID
MSL NAVAID
MSL AIRPORT

IS THE DATA CORRECT [Y]/[N]?

Press [Y] and the program will save the nav data file (because RQZ was added to it) and then go to the Navigation Menu.

AIR NAVIGATION/*RNAV*
NAVIGATION MENU

[0] MENU: The [0] key will allow you to return Main Menu.

[1] VIEW: The [1] key will display the route on the screen, along with the magnetic courses and distances for each leg. The following display is the sample flight:

```
                    TYS TO MSL
____________________________________________
                NAVIGATION

                T/DIST: 192 NM


TYS AIRPORT * TYS 221.9° 7.3 NM
 MC=245°/243°  DIST=44 NM  REM=148 NM
HCH WAYPOINT 153.1° 19.3 NM
 MC=243°  DIST=61 NM  REM=87 NM
COWAN INTERSECTION * CHA 277.0° 38.0 NM
 MC=246°/245°  DIST=38 NM  REM=49 NM
RQZ NAVAID
 MC=261°/262°  DIST=43 NM  REM=6 NM
MSL NAVAID
 MC=290°  DIST=6 NM
MSL AIRPORT

      Push any key to continue-
```

The data scrolls from the bottom of the screen. The maximum number of legs which will be visible on the screen at one time is seven. However, when the data stops scrolling there will be five legs left on the screen. [CTRL][1] will stop and restart the scrolling.

In between each nav fix are the magnetic course(s), the leg distance, and the remaining distance. In the example, notice the navigation data for the leg between McGhee Tyson airport and the waypoint off of Hinch Mountain Vortac. While using the Knoxville Vortac (TYS) for navigating the magnetic course will be 245°. However, because of the difference in the magnetic variation at Hinch Mountain, the magnetic course will be 243° when using the Hinch Mountain Vortac. The distance between McGhee Tyson airport and the Hinch Mountain waypoint is 44 nautical miles. After reaching the Hinch Mountain waypoint the remaining distance will be 148 nautical miles.

[2] PRINT: If you are using a printer, the [2] key will tell the program to print the flight. If your printer isn't online the program will re-display the Navigation Menu. After the flight has been printed the program will return to the Navigation Menu. The printout will be:

```
                    TYS TO MSL
                      192 NM
=========================================

TYS AIRPORT * TYS 221.9° 7.3 NM
 MC=245°/243°  DIST=44 NM  REM=148 NM
HCH WAYPOINT 153.1° 19.3 NM
 MC=243°  DIST=61 NM  REM=87 NM
COWAN INTERSECTION * CHA 277.0° 38.0 NM
 MC=246°/245°  DIST=38 NM  REM=49 NM
RQZ NAVAID
 MC=261°/262°  DIST=43 NM  REM=6 NM
MSL NAVAID
 MC=290°  DIST=6 NM
MSL AIRPORT
```

[3] REVERSE: Press the [3] key to view and/or print the flight route in the opposite direction. The route at the top of the menu will be reversed to show the direction of flight. As an example, if the route was: 'TYS TO MSL', Press the [3] key and it will be: 'MSL TO TYS'. By pressing the [3] key again, the route will be reversed again, back to the former direction of flight: 'TYS TO MSL'.

Sometimes when the route is calculated in the opposite direction there will be small differences in the distances, courses, and waypoints. This is because of inherent problems when navigating on a sphere. This is discussed in deeper detail in the Introduction of the section on Navigation.

To print the route from Muscle Shoals to Knoxville, first press the [3] key to reverse the flight. Verify the flight direction at the top of the

display, and press [2] to start the printout. The printout will be:

```
                    MSL TO TYS
                      192 NM
=======================================

MSL AIRPORT
 MC=110°  DIST=6 NM  REM=186 NM
MSL NAVAID
 MC=082°/081°  DIST=43 NM  REM=143 NM
RQZ NAVAID
 MC=065°/066°  DIST=38 NM  REM=105 NM
COWAN INTERSECTION * CHA 277.0° 38.0 NM
 MC=063°  DIST=61 NM  REM=44 NM
HCH WAYPOINT 153.1° 19.4 NM
 MC=063°/065°  DIST=44 NM
TYS AIRPORT * TYS 221.9° 7.3 NM
```

[4] SAVE: It is possible to save up to 26 flights on the data diskette. The name of the flight file will be the identifiers of the departure and destination points. The file name of the sample flight will be TYSMSL.

Many small airports in the United States have identifiers that begin with a number. These identifiers will not work in a flight filename if they are in the departure position, as DOS doesn't allow filenames that begin with a number. If you try to save such a flight, the program will detect the error and return you to the Main Menu. The flight would then have to be re-entered. The solution is to reverse the flight with the [3] key and the destination airport will become the departure airport. If that airport also begins with a number, then change one of the identifers by adding a "K" to the front of it.

For a flight from Osceola, Arkansas (7M4) to Little Rock, Arkansas (LIT), the filename would be "7M4LIT". That would make an illegal filename. By pressing [3] to reverse the flight the filename becomes "LIT7M4", a legal filename.

The [4] key will display the Flight Index and ask which position to store the route. Pressing the appropriate key, [A] through [Z], will tell the computer which position to store the flight route in. The program will then ask you to verify your choice. If there is a flight already stored in the position you've chosen, it will be lost when the new flight route is stored. The above question will allow you to double check and prevent

loss of data by accidently pressing the wrong key. You can back-up by pressing [N].

If the position is the one you desire, answer [Y], a YES, and the program will store the flight on the data diskette. The program will then return to the Navigation Menu.

If you decide you do not want to store the flight after the Flight Index has been displayed then answer the question, 'WHICH POSITION?', by declining entry. You'll be returned to the Navigation Menu.

It is possible to have two different routes from the same departure point to the same destination. Both routes would have the same flight filename. The program recognizes the flight files by the position they are stored in. This makes it possible to file both routes even though the names will be the same when they are listed in the Flight Index. You will have to remember the positions to differentiate them. The program will display the route after loading it, so you can be sure the correct one was loaded.

Be sure that the diskette is in the disk drive before asking the program to save the flight. Otherwise, the program will return to the Main Menu when it can't find the correct disk and the data will have to be re-entered.

LOADING THE FLIGHT: Flight routes that have been stored on the diskette are loaded into the flight file by choosing the '[2] LOAD FLIGHT' option in the Main Menu. When the [2] key is pressed the Flight Index will be displayed, and you'll be asked, 'WHICH FLIGHT?'. To exit back to the Main Menu, decline entry by pressing [RETURN].

Pressing the appropriate key, [A] through [Z], will choose the flight you want to load. The program will preview the flight route on the screen and ask: 'THIS THE CORRECT FLIGHT [Y]/[N]?'

If the answer is [Y] the program will display the Navigation Menu. If it isn't the correct route, press [N], and you'll be asked again, 'WHICH FLIGHT?'

There is no provision made for "deleting" a file. The way a flight file is removed is by storing a new flight route in that position.

PRINTER MENU: Pressing the [P] key while in the Main Menu will display the current printer codes. The top of the display will be the printer menu. The printer file originally has nulls for the printer codes.

The [0] key will take you back to the Main Menu.

Pressing the [1] key will save the printer codes to the diskette, then returns the program to the Main Menu. Changes must be saved to the diskette before they can be used in the program. If [1] is pressed without any changes having been made, the program returns to the Main Menu.

Pressing the [2] key will prompt for changes to the printer codes. Changes for the printer initialization will be made first, followed by changes in the degree symbol. After the changes have been made or declined the Printer Menu is available again.

PRINTER INITIALIZATION: After pressing [2] the display will prompt for the new printer initialization code with the question, 'INIT?'. If input is declined, no changes will be made to the initialization code.

The input may be any character that can be typed from the keyboard. Up to seven characters will be accepted, after the seventh they will be truncated. If less then 7 characters are entered, nulls will be inserted after the characters.

As an example, if you wanted to enter "&Q&L012" (which is compressed type with a left margin of 12 for the C. Itoh Prowriter) then type:

[ESC][ESC],[Q],[ESC][ESC],[L],[0],[1],[2],[RETURN]

The display shows the new printer initilization code. The new code has not been entered into the file for the printer codes, and won't be until the changes are saved to the diskette.

DEGREE SYMBOL: The prompt for the degree symbol code will be the question, 'DEG CHAR?'. If input for the degree symbol code is declined the program will display the printer menu without changing the degree symbol code.

Up to 14 characters are allowed for the degree code. The reason for so many spaces is that some printers do not have a degree symbol. In this case, you can specify a degree sympol with bit image graphics if the

printer has this capability. The following is the arrangement of the dots for a degree symbol in a 8x8 character matrix:

```
00●●●000
0●000●00
0●000●00
00●●●000
00000000
00000000
00000000
00000000
```

If the bit information is organized in a vertical column of dots with the least-significant bit at the top, the decimal code for the degree character will be:

0,6,9,9,9,6,0,0

Using the C. Itoh Prowriter printer, the command for 8 bytes of bit image graphics is "&S0008", and putting the character code with it, the following would be typed:

[ESC][ESC],[S],[0],[0],[0],[8],[CTRL][,],
[CTRL][F],[CTRL][I],[CTRL][I],[CTRL][I],
[CTRL][F],[CTRL][,],[CTRL][,],[RETURN]

After the degree symbol code has been entered or declined the program will return to the printer menu. The display will show any changes that have been made.

[1] SAVE [2] CHANGE [0] MENU

PRINTER CODES

PRINTER INIT: &Q&L012

In decimal: 27,81,27,76,48,49,50

DEGREE CHAR: &S0008♥/▪▪▪/♥♥

In decimal: 27,83,48,48,48,56,0

6,9,9,9,6,0,0

If the printer codes look correct, save them to the diskette by pressing *the [1] key*. If not, the codes can be re-entered.

AIR NAVIGATION/*RNAV*
PROGRM LIMITATIONS

NAVIGATIONAL AREA: The AIR NAVIGATION/*RNAV* program is limited to the Western half of the Northern Hemisphere. This area includes the North and Central Americas. In this area all the latitude and longitude coordinates are positive.

The area limitations shouldn't effect the usefulness of this program as aircraft that are capable of international travel will use inertial navigation systems, which do not need to rely on navaids. Additionally, by far the majority of flying by light aircraft is done in the North American Countries. It is these countries which maintain the extensive coverage of navaids which this program makes use.

EQUATOR: The equation for the course fails when traveling East or West along the equator. No provision is made in the program to correct for this error.

NAVIGATION THEORY: In navigation we are concerned with traveling from one point to another on the Earth's surface. To do this we picture the surface of the Earth on charts. A basic problem presents itself as the Earth is round, but the chart is flat. It is impossible to picture the surface of the Earth on a flat plane without some distortion.

The other problem in navigating is that the two points may be joined together by two different straight lines. The Rhumb Line is a straight line that intersects all the meridians (lines of longitude) at the same angle. It is the easiest to navigate, but the longest in distance. The Great Circle is the shortest distance between two points, however the course is constantly changing, as it crosses each meridian at a slightly different angle. Because of this constantly changing course it is impossible to accurately fly the route.

The method used in aeronautical charts to project the surface of the Earth onto a flat chart is the Lambert Conformal Conic Projection. The Lambert may be recognized by the meridians being straight lines converging at some point off the top of the chart, and the parallels (lines of latitude) are arcs of concentric, equi-distant circles. This is very apparent in the illustration of the chart's coverage on the front of the chart.

Because of the convergence of the meridians on the aeronautical charts, a straight line will intersect each meridian at a slightly different angle. In fact, the straight line very closely approximates a Great Circle, so close that for all practical purposes they are the same. Radio bearings

may be plotted directly on the chart without correction, as radio signals travel between two points in a straight line along a Great Circle.

NAVIGATION ACCURACY: The disadvantage to the Lambert chart is that the course angle will vary along the route. Normally the course angle is measured at a meridian located midcourse which will give an average course. For all practical purposes this is more than sufficient, as the distances that can be traveled in a light aircraft are short enough that the error remains insignificant.

In the AIR NAVIGATION/*RNAV* program the course angle is calculated at the meridian that intersects the departure fix. The advantage to this is the calculation time is half what it would be to calculate the average course angle. The disadvantage is the course angle at the destination fix will have all the error instead of being averaged. The amount of error is still small enough for the leg lengths that are traveled.

Because of these inherent navigation problems, sometimes when the reverse route is calculated there will be small differences in the course, distance, and waypoints. To bring the error possibilites into perspective, the sample flight's longest leg between fixes was between TYS airport and COWAN intersection and it was 105 NM. The only discrepancy was in the HCH waypoint's offset distance, and then only 0.1 NM. Discrepancies can also occur because of rounding off the last digit.

AIR NAVIGATION/*RNAV*
AUTHOR'S NOTE

It is appropriate that I explain my interest in aeronautical navigation and share my aeronautical credentials. I am a Corporate pilot with 5000 hours flying experience. In addition I am an airplane and instrument flight instructor in single and multiengine airplanes, also an advanced and instrument ground instructor. I have given over 2000 hours of flight instruction and currently still giving lessons.

Sometime back, when I flew only for pleasure, it was fun to plan for a flight. The evening before the trip, charts would be spread out over the living room floor. With plotter and flight computer in hand the trip would be plotted, measured, and planned out. As my flying matured from pleasure to vocation the luxury of leisurely planning trips disappeared. If you too, are a corporate pilot, you know that many trips come on short notice. Passengers often want to know how far and how long the trip and need the information immediately if not sooner.

Using area navigation saves flying time and that means less fuel consumed and less cost. However, this also means spreading maps out (usually more than one) and drawing a line across them. Then each waypoint needs to be plotted and recorded.

Fortunately, Theopolis, our family ATARI 800, held the solution, and it has worked out great. The AIR NAVIGATION/*RNAV* program has enabled flight routes and waypoints to be planned quickly and accurately. Passengers have been impressed with the computer planned navigation. Employers appreciate being provided flight estimates quickly with resulting time and flight cost savings. Using the computer has been a tremendous assistance to me in performing my job with a high degree of professionalism.

X. NAVIGATION THEORY AND FORMULAS

INTRODUCTION

While this section has no bearing on using the AIR NAVIGATION/*RNAV* program, it is presented to answer any questions on how the program arrives at its navigational solutions. The original formulas are presented along with the formulas in terms of Atari functions.

NAVIGATION THEORY

In navigation we are concerned with traveling from one point to another on the Earth's surface. To do this we picture the surface of the Earth on charts. A basic problem presents itself as the Earth is round, but the chart is flat. It is impossible to picture the surface of the Earth on a flat plane without some distortion.

The other problem in navigating is that the two points may be joined together by two different straight lines. The Rhumb Line is a straight line that intersects all the meridians (lines of longitude) at the same angle. It is the easiest to navigate, but the longest in distance. The Great Circle is the shortest distance between two points, however the course is constantly changing, as it crosses each meridian at a slightly different angle. Because of this constantly changing course it is impossible to accurately fly the route.

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The disadvantage to the Lambert chart is that the course angle will vary along the route. Normally the course angle is measured at a meridian located midcourse which will give an average course. For all practical purposes this is more than sufficient, as the distances that can be traveled in a light aircraft are short enough that the error remains insignificant.

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DISTANCE

The Great Circle distance between fixes is calculated by the following formulas:

$$d=\cos^{-1}[\sin(LAT)\sin(LAT')+\cos(LAT)\cos(LAT')\cos(LNG-LNG')]$$

$$\text{(Distance in NM)}=60d$$

Where: LAT' and LNG' are the coordinates of the "from" fix.
LAT and LNG are the coordinates of the "to" fix.

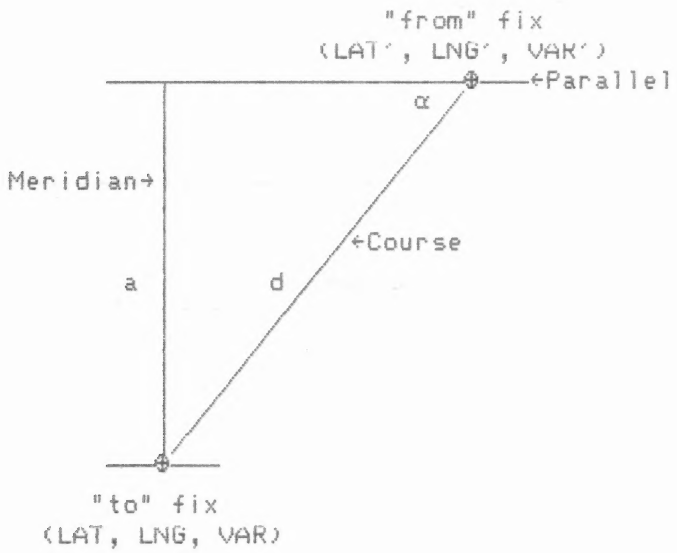
Using Atari functions the formula for d is:

$$d=90-\text{TAN}^{-1}[X/(1-X^2)^2]$$
$$X=[\sin(LAT)\sin(LAT')+\cos(LAT)\cos(LAT')\cos(LNG-LNG')]$$

COURSE

The course is derived by finding the angle "α" between the parallel passing through the "from" fix and the Course. The angle "α" is then corrected for East/West direction of travel.

A diagram illustrating the relationships is given below with the formulas:



$a=COS^{-1}(Y)$ Using Atari functions: $a=90-TAN^{-1}[Y/(1-Y^2)^2]$
$Y=[SIN(LAT)SIN(LAT')+COS(LAT)COS(LAT')]$

$d=COS^{-1}(X)$ Using Atari functions: $d=90-TAN^{-1}[X/(1-X^2)^2]$
$X=[SIN(LAT)SIN(LAT')+COS(LAT)COS(LAT')COS(LNG-LNG')]$

$\alpha=SIN^{-1}(A)$ $A=SIN(a)/SIN(d)$
Using Atari functions: $\alpha=TAN^{-1}[A/(1-A^2)^2][SGN(LAT-LAT')]$

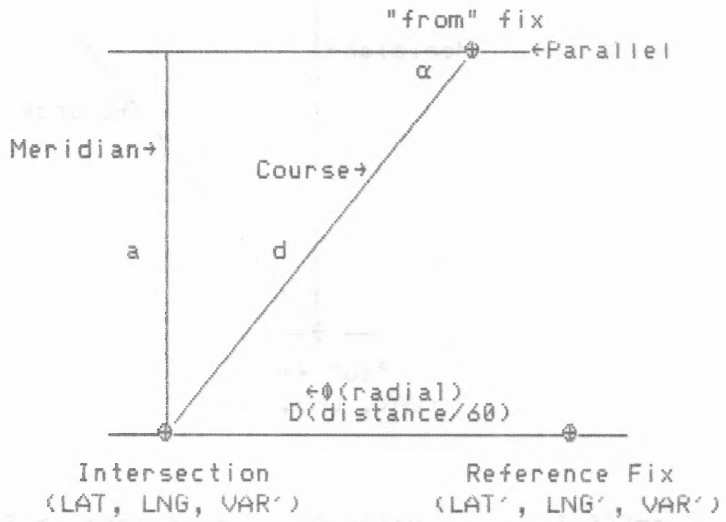
If (LNG'-LNG)<0 then TC=270+α (Westerly direction of travel.)
If (LNG'-LNG)≥0 then TC=90-α (Easterly direction of travel.)

MC=TC+VAR', and if VAR≠VAR' then MC=TC+VAR'/TC+VAR

INTERSECTIONS

Intersections are always defined by the radial (magnetic bearing) and distance from a known fix (reference navaid). The program uses this information along with the coordinates of the reference fix to derive the coordinates of the intersection. These coordinates are then used the same as the coordinates of any other fix.

A diagram illustrating the relationships and the formulas is given below:



$$LAT=LAT'+SIN^{-1}[(SIN\ D)(COS\ \Phi)]$$

$$LNG=LNG'-SIN^{-1}[[(SIN\ D)(COS\ \Phi)]/[COS[(LAT+LAT')/2]]$$

The formulas using Atari functions:

$$LAT=LAT'+TAN^{-1}[X/(1-X^2)^2]$$
$$X=(SIN\ D)(SIN\ \Phi)$$

$$LNG=LNG'-TAN^{-1}[Y/(1-Y^2)^2]$$
$$Y=X/COS[(LAT+LAT')/2]$$
$$X=(SIN\ D)(SIN\ \Phi)$$